GEOTHERMAL NOISE LEVEL GUIDELINES

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Geothermal Noise Level Guidelines

County of Hawaii

Planning Department

INTRODUCTION

In granting Special Permits for the exploration and development of geothermal resources in the Puna District, the Planning Department and Commission found that there were potential adverse impacts to the surrounding area which may result from the geothermal operations. Consequently, stringent controls and conditions were attached to the respective permits. The Planning Commission assigned the Planning Director the primary responsibility for the monitoring and enforcing of these conditions.

In light of these responsibilities and the numerous noise related complaints received from residents of the Puna District concerning certain geothermal drilling operations, the Planning Department has developed the following guidelines to determine acceptable noise levels for both geothermal exploration and production.

These noise levels are intended to provide the Planning Director with the necessary guidance to review and assess geothermal operations on a case specific basis to determine whether a noise nuisance exists or not. Based on this review, should the Planning Director find that the acceptable noise levels are being exceeded and that the residents are being significantly adversely impacted by that noise, he can: (1) invoke more stringent noise mitigative procedures and/or mitigative devices; or (2) cease further geothermal activity in accordance with the appropriate provisions of the Special Permits.

BACKGROUND

In reviewing the available literature, there are numerous guidelines which may possibly be applied to the noise problem resulting from geothermal operations. These guidelines are summarized in Table 1 below:

TABLE 1

ACCEPTABLE NOISE LEVEL STANDARDS

	NOISE LIMIT		MEASUREMENT POINT
GENERAL STANDARDS			
U.S. ENVIRONMENTAL PROTECTION AGENCY	Outdoor:	55 dBA Ldn	Nearest inhabited residence
	Indoor:	45 dBA Ldn	
U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT	Outdoor:	65 dBA Day	Residence
		55 dBA Night	
State Department of Health Community Noise regulations for Oahu	Res:	55 dBA Day	Property Line
		45 dBA Night	
	Bus/Apt	60 dBA Day	
		50 dBA Night	
	Ag/Ind	70 dBa	

GEOTHERMAL STANDARDS

U.S. GEOLOGICAL SERVICE (Federal Geothermal leases)	Outdoor: 65 dBA	Lease Boundary or 0.5 mile whichever is greater
SONOMA COUNTY, CALIFORNIA	Outdoor: 65 dBA Day 45 dBA Night	Nearest Residential Use
LAKE COUNTY, CALIFORNIA	Outdoor: 55 dBA Ldn	Nearest residential recepter

These noise standards were generally developed for urban or suburban situations and, in the case of all but the Oahu standards, for the mainland environment as well. Consequently, a factor which must be considered in viewing these various standards is the difference in the reduction of sound levels between residences in Hawaii and in the mainland resulting from different construction techniques and requirements.

For example, in establishing their community noise exposure criteria, the Federal Environmental Protection Agency used an estimated differential of 15 dBA between outdoor and indoor noise levels. The U.S. Department of Housing and Urban Development, on the other hand, used an estimated 20 dBA differential between indoor and outdoor noise. However, because of the differences in construction between the mainland and Hawaii, the actual reduction of outdoor noise levels of local residences is anticipated to be closer to 9 dBA with estimates ranging from a low of 4 dBA to a high of 15 dBA.

Furthermore, because of the rural nature of the Puna District, it may not be reasonable to compare typical local environmental noise control regulations which have evolved for urban and suburban environments.

The typical nighttime ambient noise levels of the areas surrounding the geothermal exploration area are between 30 and 35 dBA 90 percent of the time. These levels are 10 to 25 dBA less than those found in quieter suburban communties. Thus, residents near the projects have become accustomed to a very quiet acoustical environment.

The distance from noise source to listener is very great compared to most situations in heavily populated regions where noise conflicts have evolved. Thus, it is not reasonable to attempt to control noise levels at property lines of the noise making operation to meet the allowable noise levles that have evolved in urban areas where relatively short distances exist to listeners.

Thermal gradients or inversions during times of stable atmospheric conditions are apparently much more intense in rural areas than urban or industrial areas. Consequently, acoustical refraction phenomena or the bending of sound rays, becomes a major effect which must be considered. (See Appendix A on Sound Attenuation.)

GUIDELINES

In conjunction with the various acceptable noise standards and the factors specifically affecting the Puna environment, the Planning Department has developed the following noise level guidelines for geothermal activities:

1. That the acceptable geothermal noise guidelines should be at a level which reasonably assures that the Environmental Protection Agency and U.S. Department of Housing and Urban Development criteria for acceptable indoor noise levels can be met.

In general, the EPA and the HUD community noise level criteria estimate acceptable indoor noise as being between 40 to 45 dBA during the day and 32 to 35 dBA at night. These levels take into account conditions for satisfactory speech communication during the day and acceptable sleeping conditions at night. Tables 2 and 3 provides some insight into the relative noise levels as well as other studies which provide recommended sound levels for various spaces.

2. That the sound level measurements should take place at the affected residential receptors.

Given the existence of the thermal and wind gradients and consequently ground inversion conditions, it is extremely difficult to predict the source noise levels necessary to insure compliance with the noise guidelines. Consequently, until more information is available about the incidence and duration of the ground inversion conditions, measurement of the sound levels at the residential receptors will provide a reasonable means of reveiwing and assessing the impact of geothermal noise on the residents of the areas surrounding the geothermal operations.

3. That, in conjunction and appreciation of the other guidelines,

TABLE 2

Loudness and Decibels

Because hearing also varies widely between individuals, what may seem loud to one person may not to another. Although loudness is a personal judgment, precise measurement of sound is made possible by use of the decibel scale. This scale, shown below, measures sound pressure or energy according to international standards

Sound Levels and Human Response

Common Sounds	Noise Level (dB)	Effect
Carrier deck jet operation Air raid siren	140	Painfully loud
	130	
Jet takeoff (200 feet) Thunderclap Discotheque Auto horn (3 feet)	120	Maximum vocal effort
Pile drivers	110	
Garbage truck	100	
Heavy truck (50 feet) City traffic	90	Very annoying Hearing damage (8 hours)
Alarm clock (2 feet) Hair dryer	80	Annoying
Noisy restaurant Freeway traffic Man's voice (3 feet)	70	Telephone use difficult
Air conditioning unit (20 feet)	60	Intrusive
Light auto traffic (100 feet)	50	Quiet
Living room Bedroom Quiet office	40	
Library Soft whisper (15 feet)	30	Very quiet
Broadcasting studio	20	
	10	Just audible
	0	Hearing begins

This decibel (dB) table compares some common sounds and shows how they rank in potential harm to hearing. Note that 70 dB is the point at which noise begins to harm hearing. To the ear, each 10 dB increase seems twice as loud.

TABLE 3 | RECOMMENDATIONS OF SOUND LEVELS IN VARIOUS SPACES

	KNUDSEN-HARRIS 1950 dbA	BERANEK 1953 dbA	BERANEK 1957 dbA	LAWRENCE 1962 dbA	KOSTEN-VAN OS 1962 dbA	ASHRAE 1962 dbA	DENISOV 1967 dbA	KRYTER 1970 dbA	TOKYO 1971 dbA	USSR 1971 dbA	BERANEK 1971 dbA	DOELLE 1972 dbA	WOOD 1972 dbA	RETTINGER 1973 dbA	SWEDEN dbA	SWITZER-LAND 1970 dbA	CZECHO-SLOVAKIA 1967 dbA
RESIDENT																	
Home																	
Bedroom	35–45	35	35–45	25	30	25–35		40		35	34–47	35–45	35	34–42	25	35–45	40
Living Room	35–45	35		40	35	30–40		40		35	38–47		40		25	35–45	40
Apartment	35–45		35–40	30		35–45		18			34–47			38–42		35–50	40
Hotel	35–45		35–40	35–40		35–45		38		35	34–47	35–54	30–40	42		35–50	40
COMMERCIAL																	
Restaurant	50–55	55	55	40–60	50	40–55		55		55	42–52	45–60	45–50	50		40–50	55
Private Office	40–45	50	30–45	35–45	30–45	25–45	40–45	35			38–47	30–45	40–45	46	40		
General Office	45–55		40–55	40–60	60	35–65	50–60	35–40		50	42–52	45–55	45–55	50			
Transportation						35–55				60							
INDUSTRIAL																	
Workshop																	
Light		50		40–60							52–61		55–65			45–55	
Heavy		75		60–90	70		85				66–80		60–75	70		50–60	
EDUCATION																	
Classroom	35–40	35	35	30–40	30	35–45		35		40	38–47	35	35–45	38	35	35–45	
Laboratory				40–50		40–50	40–50				47–46		45–50	42			
Library	40–45	40	42–45	35–45	35	35–45		40			38–47	40–45	40–45	42			40
HEALTH																	
Hospital	35–40	40	42	20–35	35	30–45		40		25	34–47	40	40–45	38	25–35	25–35	35–40
RECREATION																	
Swimpool						45–60							50–60	50			
Sports		60	30			35–45				60		60		46			60
Gymnasium					35	40–50						55–60	45–55	46			
AUDITORIUM																	
Assembly Hall	35–40	35	35–40	40–45		30–40		38			30–42	35–45	35–45				
Church	35–40	40	40	35–40	35	25–35		40		35	30–42	35–40	35–40	38–42			
Concert Hall	30–35	30–35	25–35	25–35	30	25–35		28–35			21–30	25–35	30–35	34			35
Court Room	40–45	40	40–45	40–45	35			40			42	35–40	35–40				
Record Studio	25–30	30	25–30	20–30	20	25–35		28			21–34	25–30	30	30			
TV Studio	25–30	30	30	25–35	30	25–35		28			21–34	30–35	35	34–38			
Mot. Pict. Studio	25–30	30	25–30		25–35			25			21–34	35	25				
Mot. Pict. Theater	35–40	40	40		35	35–45		40		40		40	35–40	38			
Leg. Theater	30–35	35	30–35		25	30–40		33			30–34	30–35		34			35
OUTSIDE																	
Rural									35–45	35							
Suburb									40–50	45							
Urban									50–60								
Industrial									50–60								
Res. Areas															55		

SOURCE: EPA, *Information on Levels of Environmental Noise . . .* (1974).

the acceptable noise levels for geothermal development are as follows:

a. That a general noise level of 55 dBA during daytime and 45 dBA at night not be exceeded except as allowed under b. For the purposes of these guidelines, night is defined as the hours between 7:00 p.m. and 7:00 a.m.;

b. That the allowable levels for impact noise be 10 dBA above the generally allowed noise level. However, in any event, the generally allowed noise level should not be exceeded more than 10% of the time within any 20 minute period;

c. That the noise level guidelines be applied at the existing residential receptors which may be impacted by the geothermal operation; and

d. That sound level measurements be conducted using standard procedures with sound level meters using the "A" weighting and "slow" meter response unless otherwise stated.

SOME CONCLUDING NOTES

The guidelines for allowable geothermal noise levels are intended to provide an interim basis for assessing geothermal activites. As more information is obtained and a better understanding of both the noise levels and their impacts on the environment and the climatic conditions affecting the Puna area, these guidelines should be amended.

It is conceeded that there are problems associated with the proposed guidelines which will eventually require their amendment or the adoption of long term guidelines as more information becomes available. For example, one problem with respect to noise measurements at the receptor as opposed to the source is distinguishing between noise sources once multiple geothermal operations come on line. Accurate measurements of the various operations will have to be made to provide some baseline data. However, with the inversion conditions, it may be impossible to correctly identify the separate noise sources at the receptor.

Another problem is the cumulative impact of noise from multiple sources. Sound levels increase on a logarithmic basis when added together. That is, if there are two sources each with a 50 dBA sound level, and if both are operating at the same time, the resultant sound level will be approximately 53 dBA. Consequently, there is the potential case where all of the operators individually meet the noise guidelines, yet cumulatively, exceed it.

Consequently, as part of the overall analysis of the impacts of geothermal activities in Puna, a noise monitoring program will be implemented when the well drilling, testing, and production commence. This program should coordinate noise complaints with noise measurements, meteorological conditions and the type of operation which occured at the well site. This data could then be used to determine if there is justification to invoke more stringent noise mitigative procedures and/or devices, to reduce or increase the allowable residential receptor noise level guidelines as may be appropriate, and to establish maximum source noise level guidelines.

APPENDIX A

SOUND ATTENUATION

As sound waves move through the atmosphere, the energy of the waves are weakened (attenuated) as the distance from the source increases. The factors affecting the amount or level of attenuation include the distance traveled, the frequency of the sound waves, the relative humidity, temperature and wind velocity.

In general, there are three distict conditions or combinations of factors which affect the rate of attenuation of sound. These predicted sound propagation loss conditions (Darby, 1981) which may be applied to the Puna District are summarized as follows:

Condition 1 - Cylindrical spreading based on 3 dB loss per doubling of distance, which is the worst case theoretically. This condition exists when compound sound velocity gradients in the atmoshpere cause the ducting of sound. Excess attenuation is due only to the molecular and anomalous phenomena.

Condition 2 - Spherical spreading based on 6 dB loss per doubling of distance plus excess attenuation for propagation through air only. This condition exists when sound velocity gradients exist to "bend" sound rays over trees and other obstacles.

Condition 3 - Spherical spreading based on 6 dB loss per doubling of distance plus excess attenuation for propagation through air (Condition 2), plus ground attenuation due to the absorption and scattering caused by trees and other foliage.

The positive sound velocity gradients or ground inversions, mentioned in Conditions 2 and 3 result when sound waves are refracted or bent as they travel through the atmosphere. These inversions are normally attributed to wind or thermal gradients (changes in wind velocity or temperature over a unit distance) or combinations of both. When these ground inversions occur, they usually take place about one hour before sunset and continue to about one hour after sunrise. The conditions which contribute to the ground inversions usually exist in the atmosphere from ground level to about 200 feet in altitude.

When there are no ground inversions and ground-to-ground sound transmission is in a straight line, large excess attenuation often exists due to shielding by topographic features and buildings as well as due to absorption and scatter of sound by foliage (Condition 3). If a positive sound velocity gradient exists, then the sound rays may travel on a large arc passing above some of the obstructions, causing much less excess attenuation to be present (Condition 2). If the gradient is strong enough, it is possible that the only sound attenuation experienced by the listener is similar to a free space condtion; i.e., the result of spreading, molecular absorption and anomalous excess attenuation (Condtion 1).

In his field tests in the Puna District, Darby (Darby, 1981) found clear evidence of refraction or the bending of sound rays over obstacles due to positive thermal gradients or ground inversions. More specifically, in his comparison of the measured and predicted propagation loss data, Darby found:

(1) The propagation loss may vary by 15 to 20 dB during a 24-hour period for a given distance between source and listener..., indicating the generation and disappearance of sound velocity gradients which bend sound rays over trees and other foliage (Conditions 1 and 2).

(2) Usually propagation loss was not less than Condition 2, but there are strong indications implying that energy in the lower frequencies (125 and 250 Hz) do experience a compound sound velocity gradient at times (Condition 1).

(3) For estimating noise levels in residential areas, a reasonable average value for sound propagation loss is to use Condition 2 as a worst case understanding that when there are compound sound velocity gradients, noise levels in the low frequencies may be 5 to 10 dB greater.

These predicted sound propagation loss estimates were in part confirmed by the field measurements conducted by the Planning Department Staff on April 7, 1981. Although limited in scope and duration, these measurements confirmed the existence of the ground inversion conditions. More specifically, sound levels from the Barnwell drilling operation were measured in the Leilani Estates Subdivision which can only be explained by the Condtion 1 estimates of sound propagation loss (Moore/Nishimura, 1981a).

APPENDIX B

DEFINITIONS

The following definitions shall apply:

"A Weighted Sound Level" means a standardized decibel scale whose sensitivity varies with frequency the same way as the human ear and which reflects man's responsiveness to sound.

"Attenuation" means the lessening or weakening of sound pressure levels.

"Day - Night Sound Level (Ldn)" is the sound pressure level measurement which takes account of the fact that sounds are generally more annoying at night. It is calculted like Leq but with 10 dBA added to sound levels occuring between 10:00 p.m. and 7:00 a.m..

"Daytime" means the time period from 7:00 a.m. to 7:00 p.m. of the same day

"Decibel" means one-tenth of a bel. A unit of sound level.

A. dB - an abbreviation for decibels.

B. dBA - an abbreviation for A-weighted sound level expressed in decibels

"Equivalent Sound Level (Leq)" is the sound pressure level which over a given period of time would contain the same noise energy as the time varying sound level being described; i.e., the average energy of fluctuating noise levels.

"Excessive Noise" means any sound or sequence of sounds to which an individual is exposed and which exceeds the allowable noise level more than 10 percent of the time in any 20-minute period.

For the purpose of this definition, any sound having a duration less than one second shall be assumed to last one second.

"Impulse Noise" means any sound with a rapid rise and decay of sound pressure level, lasting less than one second, caused by sudden contact between two or more surfaces, or caused by a sudden release of pressure, including but not limited to any hammering, pile driving, and explosion. "Fast" meter response shall be used to measure these types of noise.

"Nighttime" means the time period from 7:00 p.m. to 7:00 a.m. of the following day.

"Noise" means any sound that may produce adverse physiological or psychological effects and/or interfere with individual or group activities such as but not limited to communication, work, rest, recreation or sleep.

"Noise Level" means the weighted sound level.

"Sound" means a fluctuation in air pressure which stimulates the human nervous systems through the ear, eardrums, and connecting nerves.

"Sound Level Meter" means an instrument or combination of instruments, which meets or exceeds the requirements for Type I or Type II sound level meter as specified in American National Standard Institute (ANSI) Specification for Sound Level Meters S1.4-1971 or IEC 179 or IEC 123 or their most recent approved revisions.

"Sound Pressure Level (Decibel)" means 20 times the logarithm to the base 10 of the ratio of the meaured sound pressure to the reference sound pressure of 0.0002 dynes per square centimeter or 20 micropascals.

Reference

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